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(54) Process for the in-situ removal of pollutants from the soil.

(57) The invention relates to a process for the in-situ removal of pollutants from the soil by stripping with a gas, the process being characterized in that

a. the stripping gas is injected into the soil via at least one probe near and/or under the pollutant,
b. the pollutant is volatilized with the stripping gas, so that it rises to ground level,
c. the volatilized pollutant is passed, as it rises, through a biologically active layer and is degraded there.

A plurality of probes can be placed in the soil under and/or beside the pollutant.

The stripping gas used is preferably air or ozonized air. Dry and/or heated stripping gas can be used as required.

The flow pattern of the stripping gas can be influenced by obstructions, for instance by one or more water screens round the pollutant or by airtight covers and seals applied on or in the top soil.

If the upgrading of the soil at or just below ground level to form a biologically active layer is not or hardly possible, a biologically active layer, preferably compost, can be applied on top of the soil.

The biologically active layer may contain both aerobic and anaerobic bacteria.

cross section

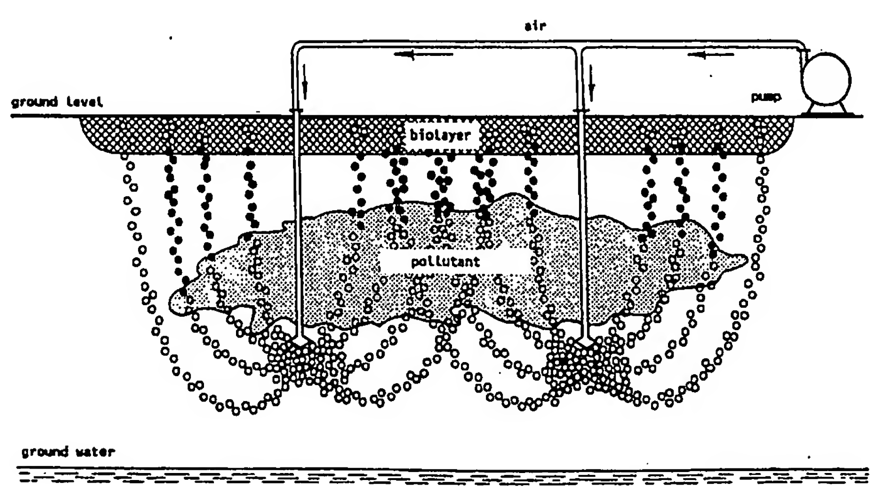

FIG. 1

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PROCESS FOR THE IN-SITU REMOVAL OF POLLUTANTS FROM THE SOIL

The invention relates to a process for the in-situ removal of pollutants from the soil by stripping with a gas.

In particular the invention relates to a process for the in-situ removal of pollutants from the deeper soil, i.e. below the furrow or even deeper.

Such a process is known from a publication by J.J.M. Hullegie, Milieutechniek 1/2 (1989) 126-131. In said publication a process is described for the removal of volatile pollutants from the soil by means of vacuum extraction, optionally in combination with compressed air injection. In the vacuum extraction process a probe is placed in the soil, which probe is used, by lowering the pressure, for sucking air from the soil, which in the process carries along the volatile pollutants. So the sucked air acts as a stripping gas. In addition, a second probe may optionally be placed, by which compressed air is injected so that an air stream is formed flowing from the compressed air injection probe to the vacuum extraction probe, carrying the volatile pollutants along with it.

A disadvantage of that process is that the sucked-up contaminated air must be collected and processed above ground level. The collection and processing of the contaminated air is done often with activated carbon and is a costly affair. The fact is that the contaminated carbon must be further processed by desorbing the pollutants, upon which the released pollutants must be processed in, for instance, an incinerator. Instead of being further processed, the contaminated carbon can be replaced by fresh activated carbon. This, too, involves a high amount of costs.

Another disadvantage of that process is the duration of the clean-up. Conventional in-situ clean-up processes normally take much time. Therefore, a clean-up period of a few years is the rule rather than the exception.

The object of the invention is to provide an in-situ clean-up process which is simple and cheap with a relatively short clean-up period.

This object is achieved according to the invention in that

a. the stripping gas is injected into the soil via at least one probe near and/or under the pollutant,

b. the pollutant is volatilized with the stripping gas, so that it rises to ground level,

c. the volatilized pollutant is passed, as it rises, through a biologically active layer and is degraded there.

Using one or more probes, a stripping gas, preferably air, is blown in under pressure under and optionally beside the pollutant. The places for the outlet(s) of the probe(s) are so selected that a maximum amount of the stripping gas moves through the polluted soil to ground level. As the stripping gas is passed through the polluted soil, the pollutant volatilizes, upon which it is carried along to ground level. If the pollutant consists of volatile materials with a sufficiently high vapour pressure (for instance acrylonitrile, benzene, toluene, perchloroethylene, or trichloroethane), such volatilization takes place by evaporation. The pollutant is carried along with the stripping gas in the form of a vapour as the gas passes through the polluted soil. Pollutants can be volatilized also by reacting them with a component of the stripping gas, for instance by an oxidant such as a stripping gas enriched with ozone obtained by ozonization of air. The reaction products formed in the process volatilize as the stripping gas passes through the polluted soil and rises to ground level. Without further measures being taken, there would be an uncontrolled escape of the volatilized pollutant to the atmosphere at ground level. In order to prevent this, the volatilized pollutant is passed, before its escape, through a biologically active layer in which the volatilized pollutant is wholly or partly degraded. This degradation can take place under aerobic conditions, for instance if the pollutant consists of acrylonitrile, benzene or toluene. Anaerobic degradation is possible also and is an advantage with pollutants such as perchloroethylene and trichloroethane.

The great advantage of the process according to the invention is that the injected stripping gas need not be sucked off and be processed at high costs. So the in-situ clean-up process according to the invention is simpler and cheaper, because vacuum extraction with its accompanying expensive installations with activated carbon and possible incinerators can be dispensed with. Also, by applying the process according to the invention a high degree of pollutant disposal can be reached already after a short time. In the process according to the invention a relatively high pressure differential can be maintained between the inflowing and outflowing stripping gas.

According to a preferred embodiment of the process according to the invention, a dry stripping gas is used. In consequence of the injection of dry stripping gas, the soil will become dry and the porosity will increase, so that the resistance against the passage of stripping gas decreases. As the soil dries out, it also holds fewer pollutants and the evaporation will be promoted.

It is possible also to heat the stripping gas. This enhances the effect of the drying of the stripping gas. In case the pollutant is converted locally

into volatile components, using for instance an oxidant, the heating of the stripping gas also results in a higher conversion rate and consequently in a shorter clean-up period. By heating the stripping gas, an optimum climate can be achieved in the biologically active layer also in cold weather. With the injection of a dry and/or heated stripping gas, however, more attention must be given to keeping the biologically active layer in good condition. For instance, the temperature in the biologically active layer can be kept at its required level with heated stripping gas and the biologically active layer can be watered as needed for maintaining the required humidity.

The flow pattern of the gas in the soil can be influenced by obstructions, for instance by using water screens. Such a screen may, for instance, consist of an infiltration trench round the pollutant. It is possible also to use airtight covers or seals, existing or yet to be applied on or in the top soil, such as for instance concrete slabs.

It is in principle possible to use a biologically active layer already present in the soil at a suitable place. However, it is an advantage for the soil to be upgraded by means of additives to form a preconditioned biologically active layer.

If the upgrading of the soil at or just below ground level to form a biologically active layer is not or hardly possible, a compost layer of a few decimetres' depth can be used, applied on top of the soil.

The process according to the invention is elucidated by means of the figures and the typical embodiment without, however, being limited hereto.

Figure 1 represents a cross section of the soil with a pollutant contained therein. Using a pump and one or more probes a stripping gas is injected into the soil under or beside the pollutant. The stripping gas rises and carries the volatilized pollutant along with it. The volatilized pollutant is subsequently passed through a biologically active layer situated at or just below ground level and totally degraded there.

Figure 2 is an experimental arrangement on laboratory scale. Stripping gas is passed by means of a pump via a flow meter through a first column of water with pollutant. The thus contaminated stripping gas is subsequently passed through a second column with a biologically active layer. After both the first and second columns samples can be taken to determine the degree of pollution.

Example I

The example is performed according to the arrangement represented in figure 2. Column 1 with a cross section of 200 cm^2 and a liquid level of 60 cm contains 12 litres of water with acrylonitrile (ACN) added to it. On commencement of the experiment the concentration in the water is approx. 200 mg/l.

Through this solution a regulatable amount of air is blown. The air absorbs ACN from the solution and is subsequently passed into the bottom of column 2. Column 2 with a cross section of 314 cm^2 and a filling height of 60 cm contains 21.5 kg soil provided with additives, for instance fertilizers, compost, structure conditioners, biologically active material and trace elements. With these additives to the soil a biologically active layer is obtained. The air flow through the columns is regulated by means of a flow meter. This flow meter is calibrated to the discharge rate of column 2.

The ACN concentration in the material fed to and discharged from column 2 is analyzed daily using Gastec tubes. In these analyses, Gastec tubes ranging from 0.1-24 ppm (v) were used from day 1 up to and including day 31 and from day 32 up to and including day 57 Gastec tubes were used ranging from 0.1-300 ppm (v). Besides, these analyses were checked gaschromatographically (GC). At regular times the ACN concentration of the water in column 1 was restored to its required level again by addition of ACN.

The progress of the measurements and the results are shown in diagrams 1 and 2. The measuring was started with an air flow rate of 12 l/h. At this moment the biologically active layer is found yet to be insufficiently adapted to the ACN; the concentration upon discharge from column 2 rises quickly. With an air flow rate of 5 l/h, the ACN concentration upon discharge from column 2 subsequently falls to below the detection limit. This remains, even if after 6 and 10 days the flow rate of the air is increased to 12 and 18 l/h respectively. An increase to 25 l/h, however, results in an overloading of the biologically active layer. On the other hand, immediately after the lowering of the air flow rate to 18 l/h, the ACN concentration upon discharge from column 2 falls to below its detection limit again.

On the basis of these measuring data it can be calculated that, with an air load of up to about 20 l/h (0.6 $m^3/m^2.h$) and ACN concentrations of 600 mg/m^3 in the feed, the disposal efficiencies achieved by the biologically active layer are more than 99.9%. In terms of volumes this means a specific conversion rate of at least 600 mg ACN/m^3.h. On the basis of the measuring results it can be concluded also that the removal is not connected with the adsorption of the ACN, but the result of biological degradation.

Example II

Example I was repeated on the understanding that column 1 contained 12 litres of water with benzene added to it instead of ACN. The progress of the measurements and the results are shown in diagrams 3, 4 and 5. The measuring was started with an air flow rate of 5 l/h containing 360 ppm (v) benzene. The benzene concentration upon discharge from column 2 was 0.5 ppm (v). Within 4 days the air flow rate was increased to 10 l/h and the benzene concentration upon discharge from column 2 remained 0.5 ppm (v). After 9 days the air flow rate was increased to 20 l/h and the benzene concentration was also increased to 900 ppm (v). This, however, resulted in an overloading of the biologically active layer. On the other hand, immediately after the lowering of the air flow rate to 10 l/h, the benzene concentration upon discharge from column 2 fell back to 0.5 ppm (v). After 14 days the air flow rate was increased to 15 l/h with a benzene concentration of 625 ppm (v). The benzene concentration upon discharge from column 2 remained 0.5 ppm (v). After 16 days the air flow rate was further increased to 20 l/h containing 715 ppm (v) benzene. This resulted in an increase of the benzene concentration upon discharge to 2 ppm (v). A further increase of the air flow rate to 25 l/h resulted again in an overloading of the biologically active layer as the benzene concentration upon discharge increased further to 3 ppm (v). However, immediately after the lowering of the air flow rate to 5 l/h, the benzene concentration upon discharge from column 2 fell back again to 0.5 ppm (v). Finally, after 28 days the biologically active layer was adapted thusfar that it could cope sufficiently with an air flow rate of 30 l/h containing 810 ppm (v) benzene. The benzene concentration upon discharge from column 2 remained 0.5 ppm (v).

On the basis of these measuring data it can be calculated that, with an air load of up to about 1 $m^3/m^2.h$ and benzene concentrations of 4200 mg/m^3 in the feed, the disposal efficiencies achieved by the biologically active layer are more than 99.9%. It can be concluded also that the removal is not connected with the adsorption of the benzene, but the result of biological degradation.

Claims

1. Process for the in-situ removal of pollutants from the soil by stripping with a gas, the process being characterized in that

   a. the stripping gas is injected into the soil via at least one probe near and/or under the pollutant,

   b. the pollutant is volatilized with the stripping gas, so that it rises to ground level,

   c. the volatilized pollutant is passed, as it rises, through a biologically active layer and is degraded there.

2. Process according to claim 1, characterized in that the stripping gas is air or ozonized air.

3. Process according to any one of claims 1-2, characterized in that a plurality of probes are placed in the soil under and/or beside the pollutant.

4. Process according to any one of claims 1-3, characterized in that dry stripping gas is used.

5. Process according to any one of claims 1-4, characterized in that heated stripping gas is used.

6. Process according to any one of claims 1-5, characterized in that the flow pattern of the stripping gas is influenced by one or more obstructions.

7. Process according to claim 6, characterized in that the obstruction consists of a water screen round the pollutant.

8. Process according to claim 6, characterized in that the obstruction consists of an airtight cover or seal applied on or in the top soil.

9. Process according to any one of claims 1-8, characterized in that the soil is upgraded with additives to form a preconditioned biologically active layer.

10. Process according to any one of claims 1-8, characterized in that a biologically active layer, preferably compost, is applied on the soil.

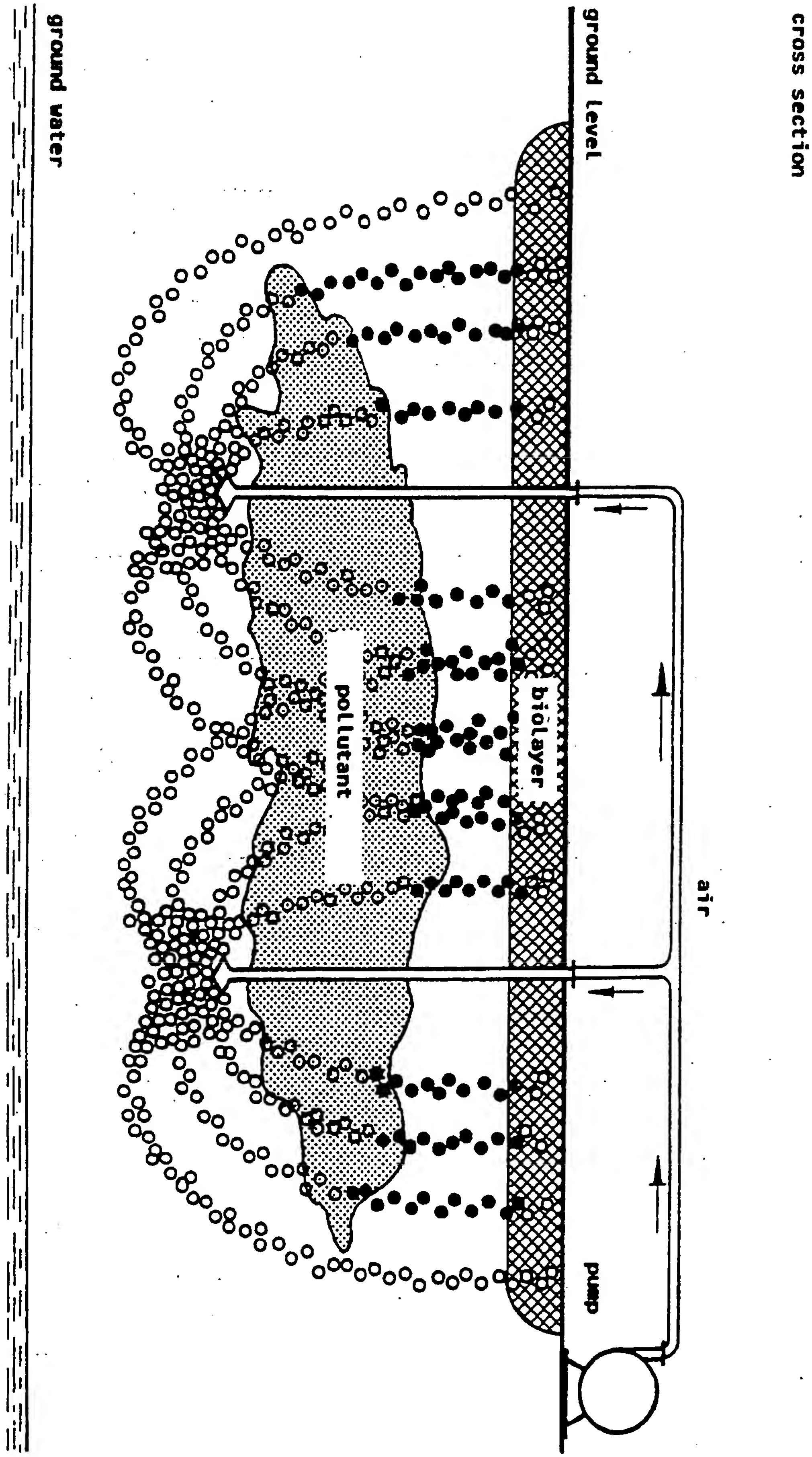
cross section
ground level
biolayer
pollutant
air
pump
ground water

FIG. 1

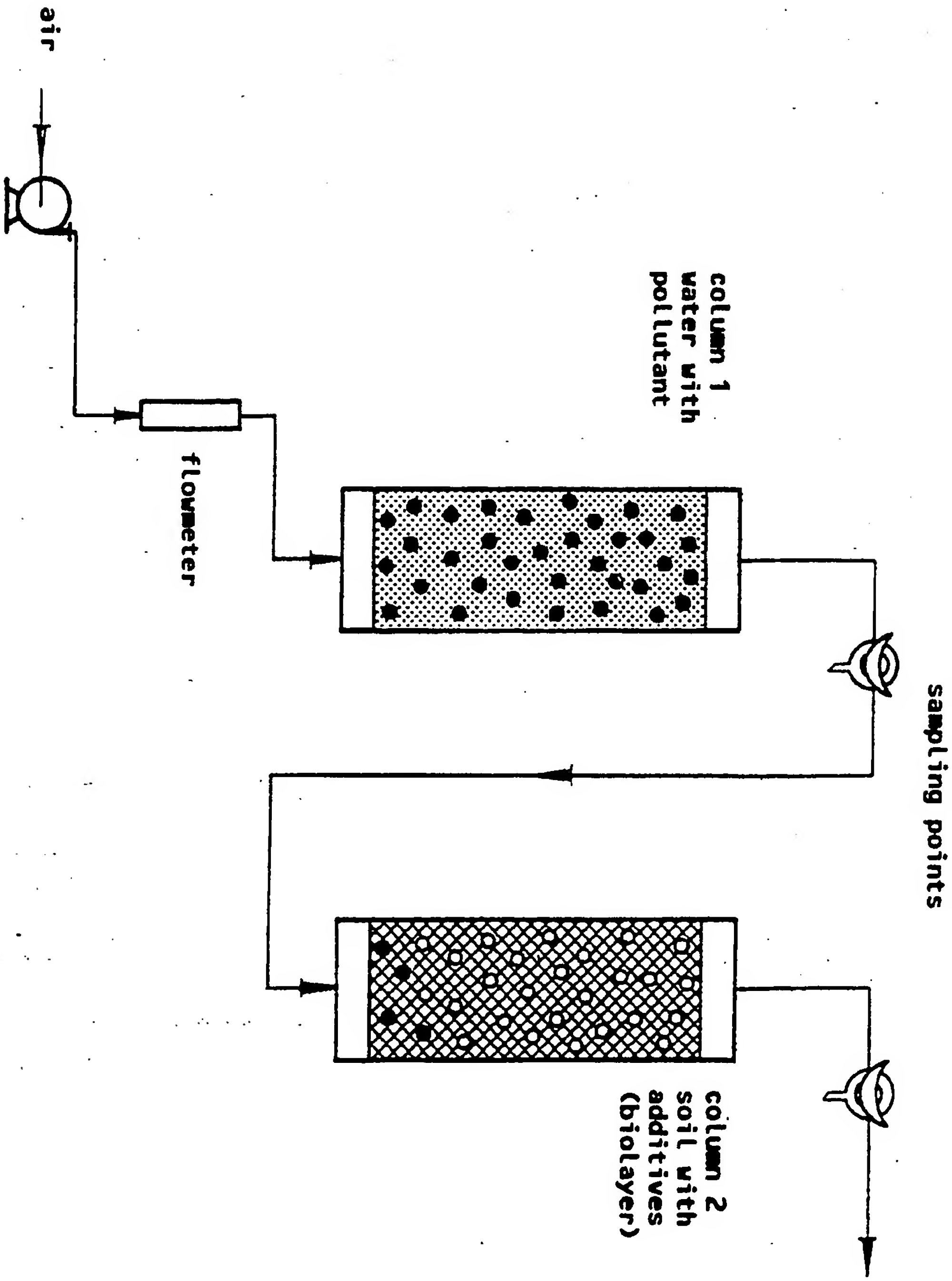
air
flowmeter
column 1
water with
pollutant
sampling points
column 2
soil with
additives
(biolayer)

FIG. 2

ACN degradation in biolayer
offgas concentration

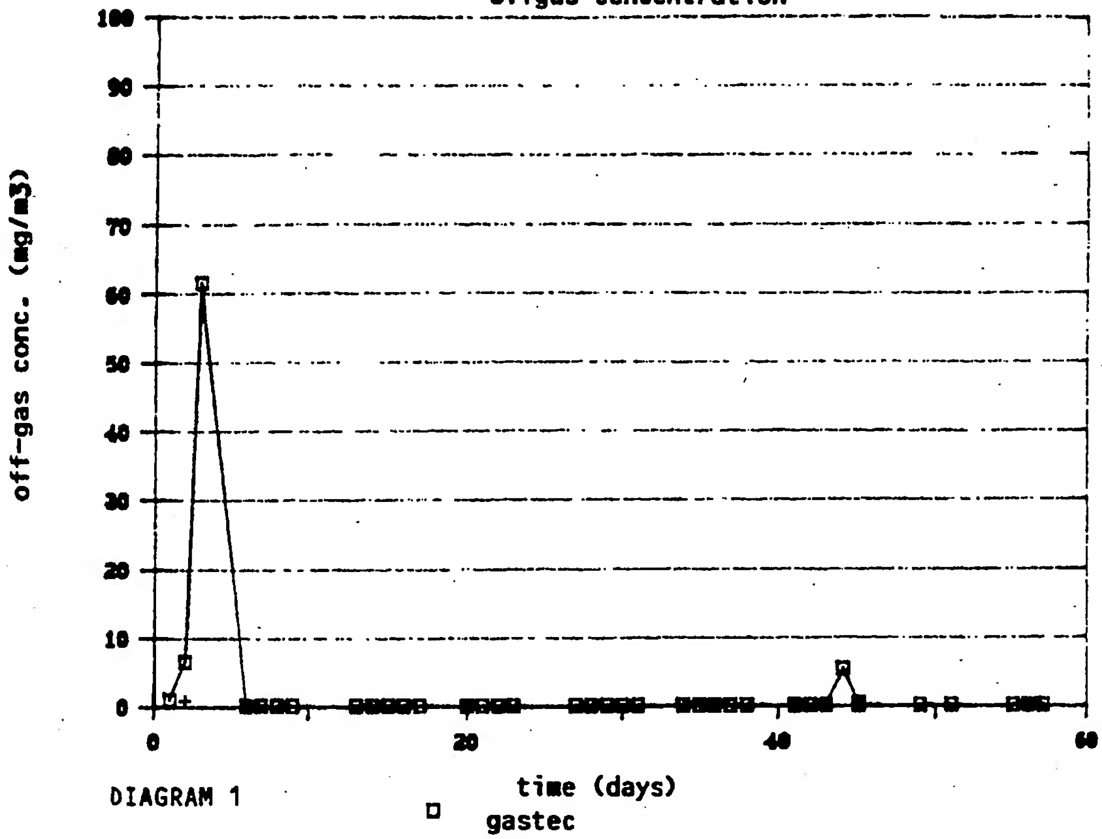

DIAGRAM 1

ACN degradation in biolayer
air flow rate

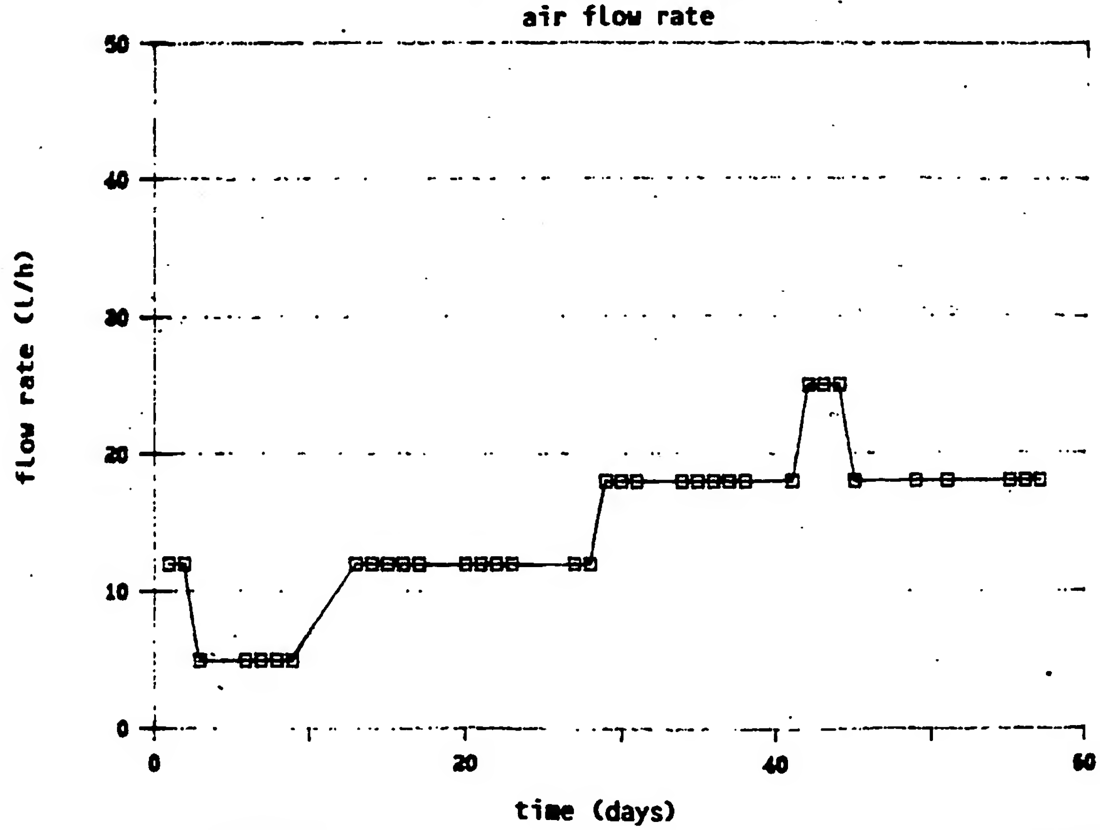

DIAGRAM 2

benzene-degrad. in biolayer

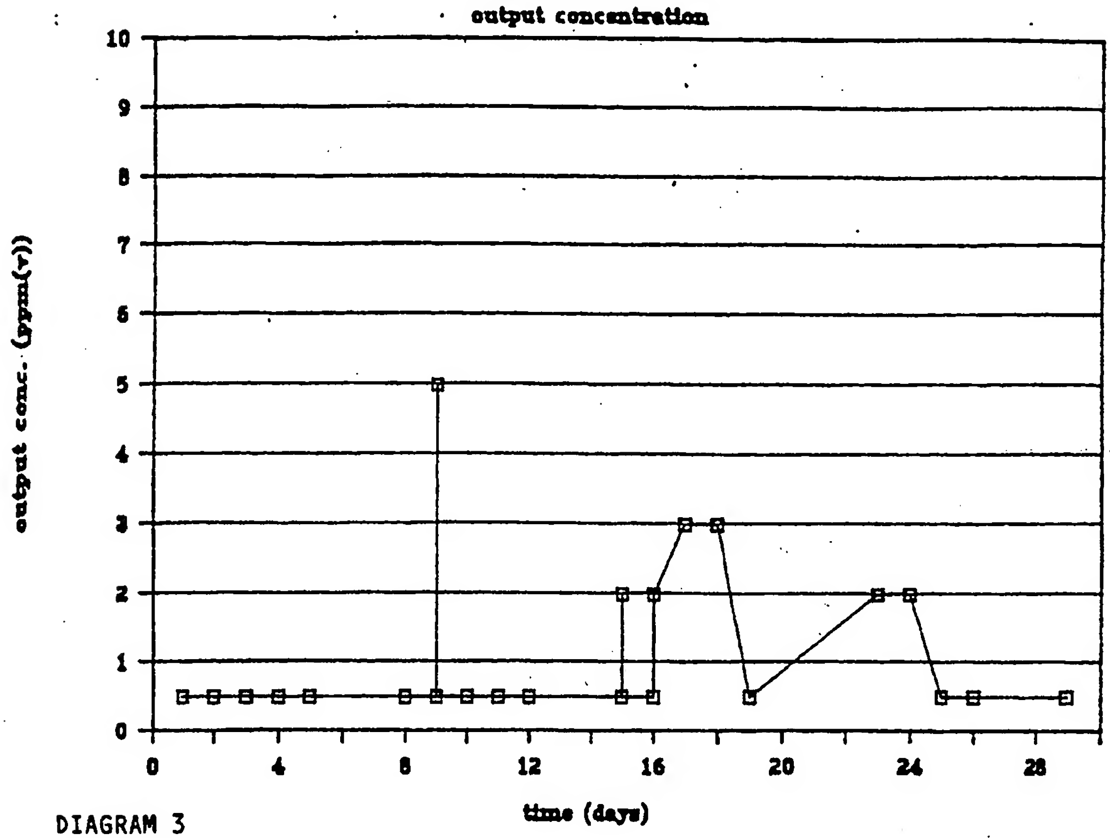

DIAGRAM 3

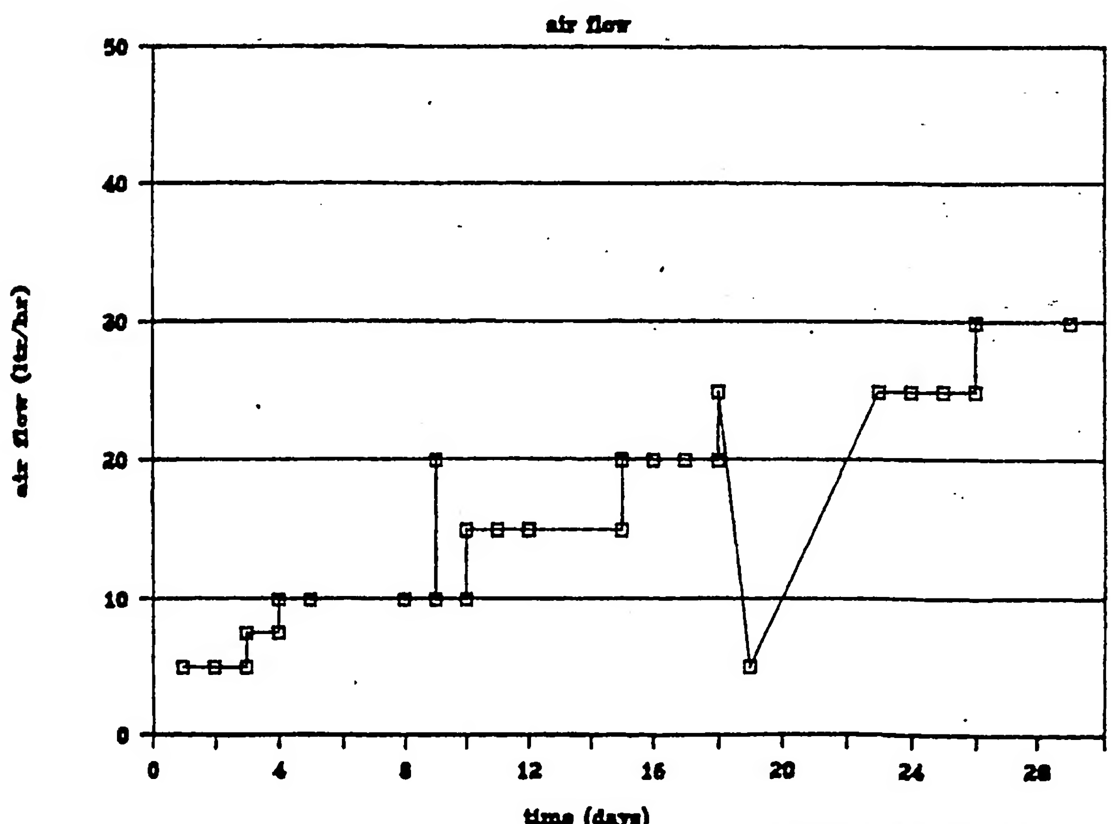

DIAGRAM 4

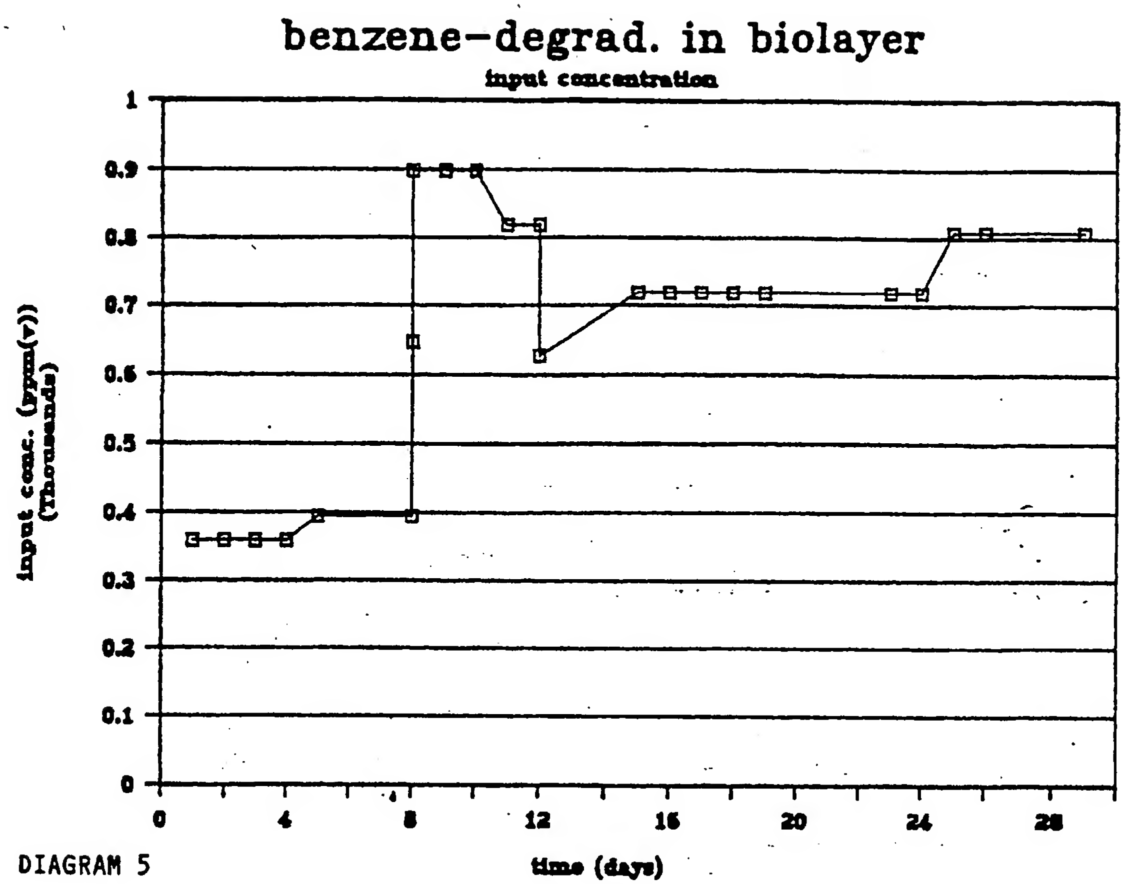

DIAGRAM 5

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EUROPEAN SEARCH REPORT

Application Number

EP 90 20 3043

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	DE-A-3 601 490 (H. HÖLTER) * The whole document * – – –	1-6,8,9	B 09 B 3/00 A 62 D 3/00 B 01 D 53/00
Y	CHEMIE INGENIEUR TECHNIK, vol. 59, no. 6, 1987, pages 457-464, VCH Verlagsgesellschaft mbH, Weinheim, DE; W.-D. DECKWER et al.: "Technologien zur Sanierung von Bodenkontaminationen und Altlasten" * Page 458, column 2, line 9 - page 459, column 1, line 1; page 462, column 1, lines 3-21; figure 2 * – – –	1-6,8,8	
A	DE-A-3 739 126 (R. SCHÜTTE) * Column 1, lines 1-49; column 4, lines 23-26 * – – –	1,2	
A	BWK BRENNSTOFF WÄRME KRAFT, vol. 41, no. 3, March 1989, pages L24-L29, Düsseldorf, DE; D. EITNER: "Biofilter in der Abluftreinigung, Biomassen-Planung-Kosten-Einsatzmöglichkeiten" * The whole document * – – –	1,10	
A	CHEMICAL ENGINEERING, vol. 95, no. 6, 25th April 1988, pages 73-76, New York, US; H. BOHN et al.: "Soil beds weed out air pollutants" * The whole document * – – –	1	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	DE-A-3 815 164 (WESSLING) * Claims 1-5 * – – –	1,2	B 09 B B 01 D
A	GB-A-2 098 644 (SHELL) * Page 1, lines 45-97; page 3, lines 93-102; figure * – – –	1,2	
A	US-A-4 593 760 (M.J. VISSER) – – – -/-		

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	01 February 91	LAVAL J.C.A

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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A: technological background
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P: intermediate document
T: theory or principle underlying the invention

E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 20 3043

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-4 765 902 (D.L. ELY) – – –		
D,A	MILIEUTECHNIEK, no. 1/2, 1989, pages 126,129,131, Oisterwijk, NL; J.J.M. HULLEGIE: "Vluchtige stoffen saneren met vacuüm-extractie en persluchtinjectie" – – – – –		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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The Hague	01 February 91	LAVAL J.C.A

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention

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D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document